# Homogeneous liquid-liquid extraction of metals with ionic liquids

*Bieke Onghena, KU Leuven, Heverlee (Leuven), Belgium; Koen Binnemans, KU Leuven, Heverlee (Leuven), Belgium*

Ionic liquids (ILs) are intensively studied for use in solvent extraction. Attractable properties such as negligible vapor pressure, non-flammability, broad liquidus range and high thermal stability, makes ionic liquids interesting replacements for the environment damaging volatile organic solvents (VOCs). However, most ionic liquids are characterized by a high viscosity, which is a serious drawback for use in solvent extraction. Due to their high viscosity, a large energy input and long mixing times are required to reach equilibrium conditions.

*Homogeneous liquid-liquid extraction* (HLLE) with ionic liquids is introduced as a modified solvent extraction technique to cope with these problems. HLLE makes use of solvents showing thermomorphic behavior in combination with water. This means that the phase behavior of the IL-water mixture is temperature-dependent. Heating of the extraction mixture above the critical temperature or cooling below it (depending on the type of phase behavior) leads to the formation of one homogeneous phase, which eliminates the need for intense stirring during the mixing stage of the extraction. In this homogeneous stage, extraction is no longer kinetically hindered by a barrier interphase. As a result the extraction equilibrium is reached practically instantaneously. During the settling stage, the temperature is changed in such a way that the two phases are reformed.

The scope of our work was to find an efficient homogeneous liquid-liquid extraction system to extract metal ions with a critical temperature close to room temperature (hence little energy is required to reach the homogeneous stage). The ionic liquid [Hbet][$Tf_2N$], with an upper critical solution temperature (UCST) of 55.5 °C, was shown to extract Ga, Sc, In and the most important rare earths with high extraction efficiencies in combination with betaine as extractant.[1] The extracted metals were stripped from the loaded ionic liquid phase with hydrogen chloride. At the end of the extraction, pure ionic liquid was recovered, which could be used for new extractions.

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[1] Vander Hoogerstraete, T.; Onghena, B.; Binnemans, K. Homogeneous Liquid-Liquid Extraction of Metal Ions with a Functionalized Ionic Liquid. *J. Phys. Chem. Lett.* **2013,** *4* (10), 1659-1663.